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ABSTRACT

Reported are results of a survey and a forecast of the number of science doctorates in the United States by the year 1980, of 350,000. The magnitude was determined through examination of the 1968 group, estimates of death and retirement attrition, projections of emigration and immigration patterns, and projections of doctorates produced between 1968 and 1980. Appendices include results of the survey according to: (1) 1968 utilization of Ph.D. Personnel in Science and Engineering; (2) Projected Availability of Science and Engineering Doctorates; (3) Projected 1980 Utilization of Ph.D. Scientists and Engineers; and (4) Possible Modifications of Utilization Patterns. (JG)

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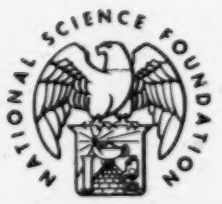

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Foreword

The relationship between the supply of scientific and engineering manpower and the needs of our society pervade almost all aspects of science policy as well as the planning for higher education and for its support. During periods of acute shortages of scientists and engineers, definitions of issues are somewhat simpler in that it is evident that overt actions have to be taken to increase this segment of our high-level professional population. Furthermore, in the past, steady trends of government support of research and development, of student career choices, and of educational patterns made assessment of future situations easier.

However, the situation has changed. We find ourselves in a period of readjustment of manpower relationships, student interests, and financial support. While some of these changes may well be of a short-range nature, others are unquestionably more fundamental and thus of longer duration. Rapid change produces temporary misalignments, doubts, and deep concern. Thus, it is especially important during such a transition period to prevent exaggerations, to distinguish painful short-term effects from long-range ones which may have much greater impact, and to examine carefully various alternatives. It is exactly this situation which led the National Science Foundation to initiate this particular study of the expected future relationship between the supply and utilization of science and engineering doctorates.

The NSF has always played a major role in the collection of data and analyses related to this Nation's scientific manpower. On the basis of this experience it was fully realized that in projective analyses, such as this one, no false sense of precision should be attributed to numerical values in view of the limitations of the data and methodologies, the complexity of the system, and the unpredictability of future events. However, the inherent long-range factors involved in the training and utilization of doctorate manpower, such as the period required to produce a Ph.D. scientist, and the time required to achieve changes in utilization patterns, do make a study of this type meaningful. It can produce broad indications of balances or imbalances and can provide insight as to the quantitative and qualitative effects of variable parameters.

The year 1980 was selected for the projection in view of the long lead time involved in the process of producing doctoral scientists. Those doctorates produced between now and 1980 will constitute the major proportion of the body of doctorate scientists available at that time. Median elapsed time between the baccalaureate and doctorate in science is now 7-8 years, and the registered time in course and research work is about 5-6 years. Furthermore, program revisions, which affect the number of graduate students or the average length of graduate study, are likely to be slow in working through the system, so that 10 years or so are needed for the full effects to be apparent.

This study suggests that alternatives will be possible in the 1970's, which permit the utilization of science and engineering doctorates in additional activities for which they are well qualified, but for which the supply has been inadequate in the past. These activities contribute significantly to our scientific, economic, and social progress. Furthermore, these analyses indicate that probably we can only achieve those societal benefits if the present trends in doctorate production can be maintained. Thus, the desirability of alternative utilization patterns must be carefully examined before any overt steps are taken to affect quantitative aspects of graduate education in the sciences. Such steps might not only destroy the favorable margins projected here, but may also disrupt the basic production system, which has made this country preeminent in scientific development. At the same time, it is clear, not only from this study but also from recent experiences, developing societal needs, and student aspirations, that university programs and present degree structures should be carefully reexamined at this time.

While many staff members of the NSF Planning Organization contributed to these analyses, the primary authors of this paper are: C. E. Falk, R. W. Cain, and L. M. Hartman. The comments and assistance of J. Lewis, T. J. Mills, K. Sanow, and S. Reed, were especially helpful. We are also grateful to the many individuals who reviewed this study and provided thoughtful comments and suggestions.

Charles E. Falk
Planning Director
National Science Foundation

November 1969

Contents

	Page
INTRODUCTION	1
SUMMARY AND CONCLUSIONS	3
1968 Supply and Utilization	3
Projected 1980 Supply	3
Projected Basic 1980 Utilization	4
Modified, Improved 1980 Utilization	5
APPENDIXES:	
A. 1968 Utilization of Ph.D. Personnel in Science and Engineering	9
B. Projected Availability of Science and Engineering Doctorates	13
C. Projected 1980 Utilization of Ph.D. Scientists and Engineers	21
D. Possible Modifications of Utilization Patterns	28
E. Selected Bibliography and Sources of Data	33

Text Tables

Tables

Page

1. "Basic" utilization of doctorate scientists in 1980 (Method I) 4
2. "Basic" utilization of doctorate scientists in 1980 (Method II) 5
3. Modified utilization of doctorate scientists in 1980 5

Appendix Tables

A-1. Estimated supply of Ph. D. scientists and engineers, January 1968 9

A-2. 1968 utilization of Ph.D. scientists and engineers, by sector and field 10

A-3. 1968 utilization of Ph.D. scientists and engineers, by sector and work activity 11

A-4. 1968 utilization of Ph.D. scientists and engineers, by field and work activity 11

B-1. Summary of availability of science and engineering doctorates, 1968 to 1980 13

B-2. Graduate enrollment and enrollment for advanced degrees and doctorates awarded in science and engineering, 1960-61 to 1979-80 14

C-1. 1980–Basic utilization projections 21

C-2. Utilization of Ph.D. scientists and engineers, by sector and work activity estimated for 1980 (Method I) 22

C-3. Total R&D and Federal R&D expenditures, 1968 and projected to 1980, by sector 22

C-4. Utilization of Ph.D.'s in research and development, 1968 and 1980 23

C-5. Projected utilization of Ph.D.'s in teaching activities in universities and colleges, 1980 23

C-6. Basic projection of utilization of 1980 Ph.D. scientists and engineers (Method II) 25

D-1. 1980–Modified utilization projection of Ph.D.'s 29

D-2. Modified projected utilization of Ph.D.'s in research and development in 1980 29

D-3. Summary of modifications to basic 1980 utilization (Method I) 30

D-4. Summary of modifications to basic 1980 utilization (Method II) 32

Introduction

The question of supply and demand of doctoral-level scientists[1] plays a central role in national science planning. It relates to such issues as: the amount and utilization of future R&D funds, the need to stimulate students to enter the field of science, the number and size of graduate schools needed, the type of graduate training required, etc. Projections of Ph.D. scientists available 10-15 years from now are likely to correspond to the actual future situation, because most are already either in these professions or are in the academic "pipe-line." On the other hand, it is extremely difficult to predict the national demand for these professions. As a matter of fact, the concept of absolute manpower "demand" seems inappropriate. What can be discussed is the expected *utilization* of doctoral scientists with the realization that the magnitude and nature of this utilization will be affected by the available supply. However, this complex relationship is difficult to anticipate. The larger the relative supply, the more varied the types of activities for which Ph.D. scientists will be used. Furthermore, in periods of relative short supply, some tasks ordinarily undertaken by doctorates will simply not be fulfilled or will have to be redesigned so that professionals with lesser educational background can carry out part of the overall effort, even though generally less effectively.

Because of the constant requests for numerical projections and despite these inherent difficulties, an attempt has been made to develop forecasts for the year 1980 in order to provide some quantitative indication of the general nature of the probable supply-utilization relationship for doctoral scientists and engineers. The year 1980 was selected in view of the long time involved in the doctoral scientist production process. The median elapsed time between the baccalaureate and doctorate in science is 7-8 years, and the registered time in course and research work is about 5-6 years.

It will be evident from a review of the methodologies and assumptions used that the forecasts are characterized by relatively large uncertainties. Thus, no false sense of precision should be attributed to the numerical values of the projections. At best, the range of numerical values should be considered as an indication of the extent of any future balances or imbalances.

Difficult as these utilization and supply projections are for the total doctorate group, they are even more difficult to make on a field of science basis. This is due to the fact that on the supply side trends depend on various unpredictable factors, such as student interests and concerns, response to feedback from the employment market, motivational factors dependent on such considerations as Government support of specific

[1] The generic term "scientists" will be used to indicate both scientists and engineers.

fields of science and technology, etc. In the case of utilization, the field distribution will be affected by the nature of governmental R&D programs, the development of new and diverse industries, student interest in various fields of science (with inherent uncertainties just described as part of the supply situation), etc. Since most of these factors are essentially unpredictable over a 10-year period, no projections by field of science are made in this paper; it is believed that such projections would be almost meaningless.

The next section summarizes the results of these analyses, as well as giving very brief descriptions of the methodologies used. The material is covered in considerably more detail in the various appendixes.

Summary and Conclusions

These analyses forecast by 1980 a supply of about 350,000 science doctorates. Utilization projections have been made on the basis of recent activity patterns or trends. These are considered "basic" or conservative since they reflect a Ph.D. shortage situation and an era characterized by very tight Federal R&D budgets due to unusual, temporary fiscal demands. These "basic," minimal utilization levels are projected within a range of about 275,000-300,000 science doctorates, depending upon the methodology used. However, improvements of the present situation are quite desirable from a national point of view. Thus, modifications to the "basic" utilization projections were considered which reflect either a recovery of national R&D funding growth rates to those experienced in the 1953-66 period; increases in doctorate to total faculty ratios in post-secondary institutions of higher education; increases in the rate of growth of that section of the Ph.D. population which will be involved in nonacademic, or non-R&D activities; or a combination of all these factors. Projections based on realization of only several or all of these modifications of the "basic" science doctorate utilization indicate possible 1980 utilization levels as high as about 390,000 doctorates.

Thus, the expected number of science doctorates lies about half way between the "basic" and the "improved" utilization projections. It would therefore appear that present and projected trends in Ph.D. production rates are not likely to produce an "over-supply" of doctorates. On the other hand, if these supply trends can be maintained it will be possible to provide some qualitative and quantitative improvement in the patterns of utilization of science Ph.D.'s.

This analysis points to one very important issue, namely that significant numbers of Ph.D.'s are likely to be engaged in activities which are markedly different from those practiced by most present doctorate holders. It is therefore very important that new Ph.D.'s be offered options of graduate programs including some that are most suitable for these new activities. Furthermore, students must not be educated with "false" aspirations for solely research careers. This training issue will make it necessary for universities to examine their graduate programs and probably to develop different and new programs for Ph.D.'s who do not intend to enter research careers. At the same time it is very important that society, especially its academic component, transmit to graduate students an awareness that nonresearch careers play an important role in both national and scientific affairs.

1968 Supply and Utilization

It is estimated that, as of January 1968, the number of Ph.D.-level scientists employed in various activities in the United States was approximately 147,000. This estimate was calculated from the numbers of earned doctorates awarded in the years 1920 through 1967 from U.S. institutions, less attrition caused by death and retirement, less allowances for those persons (almost entirely women) not undertaking a career in science or engineering, and less allowances for those foreign citizens who earned Ph.D.'s in the United States but subsequently left the country, or conversely, came to the United States with foreign doctorate degrees. (See appendix A.)

Nearly three-fifths (87,000) of the 147,000 doctoral scientists in 1968 were employed by universities and colleges, another one-quarter (39,000) were in private industry, and the remaining one-eighth were employed by government agencies and other organizations (14,000 and 7,000 respectively).

Projected 1980 Supply

The magnitude of the group of doctoral scientists available in 1980 was determined through an examination of the present (1968) group, estimates of death and

retirement attrition, projections of emigration and immigration patterns, and projections of doctorates produced between 1968 and 1980. (See appendix B.) The latter were generated by NSF on the basis of enrollment projections developed by the Office of Education. The net result indicates that by 1980 there will be approximately 350,000 doctoral scientists in the United States. Most of these are already in existence, or are either in institutions of higher education or about to enter them. While there are some indications of shifts in student interests, these have not yet produced significant changes in the fraction of undergraduate or graduate degrees awarded in the overall science and engineering (including social science) area. However, it should be pointed out that major changes in student interest in graduate education in general or in the sciences could lower the projected Ph.D. supply significantly.

Doctorate supply projections depend on future science enrollments in both graduate and undergraduate schools. Since graduate enrollments are increasing faster than bachelor of science production, one should analyze whether the projected Ph.D. production rates appear realistic on the basis of the number of bachelor's produced. Such analyses indicate that these differential growth rates will not produce any Ph.D. production limitations by 1980. However, continuation of present trends may produce a problem several decades from now.

Projected "Basic" 1980 Utilization

Two somewhat different methodologies were used to project the pattern of utilization in 1980, the fundamental difference being the treatment of academic faculty and nonacademic utilization of scientists. "Basic" projections, which represent conservative, minimal levels, assumed essentially a continuation of the same type of work activity and quality patterns as are in existence today, i.e., constancy of ratios of student/faculty, doctorate faculty/total faculty, doctorate scientists/nondoctorate scientists in nonacademic activities, etc. On this basis and the methodologies described below, lower limit utilization numbers in the range of about 275,000-300,000 science doctorates are anticipated.

Method I

From existing data,[1] the present-day group of science doctorates was divided on the basis of "primary employment," into three groups: those involved in Research and Development, Teaching, and Other Activities.

[1] From surveys of employment of scientists and engineers in industry, universities and colleges, nonprofit organizations, and the Federal Government, and from the National Register of Scientific and Technical Personnel.

The number of those likely to be involved in research and development was computed on the basis of probable future R&D funding levels (constant 1968 dollars). This assumes that the R&D dollar/doctorate scientist ratio will remain unchanged in each economic sector. This projection of the possible magnitude of 1980 R&D expenditures assumes that 1980 Federal R&D obligations and total academic R&D support will still represent about the same fraction of GNP as in 1968; this implies an annual rate of growth of about 4.4 percent (constant 1968 dollars). The rate of increase of non-Federal R&D support in industrial and nonprofit organizations combined was assumed to continue along trends of the recent past, i.e., at 7.6 percent per year. Under those assumptions, total national R&D support would increase at an annual rate of 5.7 percent (1968 dollars).

Estimates of doctorates who will be engaged in postsecondary teaching are based on anticipated total enrollments in higher education and assume no changes in student/doctorate ratio or fraction of teaching faculty with doctorates.

Finally, it is assumed that the proportion of doctorates engaged in all other activities to the total number of doctorate scientists will continue to increase at about the rate observed during the last 8 years, namely about 4 percent per year.

The total "basic" utilization estimates resulting from these calculations are shown in table 1.

Table 1.—"BASIC" UTILIZATION OF DOCTORATE SCIENTISTS IN 1980 (METHOD I)
(000)

Primary employment	Doctorate scientists
Total	277
Research and development	134
Teaching	88
Other activities	55

Method II

In this method three somewhat different utilization subgroups are used: nonacademic research and development, academic (including all activities, i.e., teaching, research and development, and other), and nonacademic other.

The nonacademic R&D doctorates were calculated on the basis of likely future funds available for this activity. These were projected by using a GNP growth rate of 4.4 percent (constant dollars) and by maintaining the same

rate of growth (2.2 percent per year) in the ratio of industrially funded R&D/GNP which has been experienced since 1956. A similar method was used to determine the future level of nonfederally funded research and development at nonprofit organizations. Federally funded nonacademic R&D levels were computed by using the average ratios for the "Federal administrative budget/GNP" and "R&D/administrative budget" experienced over the 1956-68 period and applying them to the anticipated 1980 GNP level.

The academic utilization of doctorates, regardless of activity, was calculated on the basis of future enrollments. However, since different rates of growth are expected in the various subunits of the academic universe (graduate, undergraduate and 2-year), separate calculations were made for each one of these. Again, it was assumed that student/faculty and doctoral faculty/total faculty ratios will remain constant. Postdoctorates clearly are not necessarily related to student enrollment and were projected on the basis of the growth calculated for nonacademic R&D support.

Finally, the number of doctorates likely to be engaged in "other activities" was calculated through application of the same methodology as that used in Method I.

The result of these computations are shown in table 2.

Table 2.–"BASIC" UTILIZATION OF DOCTORATE SCIENTISTS IN 1980 (METHOD II)
(000)

Subgroups	Doctorate scientists
Total	301
Academic	177
Nonacademic research and development	87
Nonacademic other	37

Modified, Improved 1980 Utilization

The "basic" projections reflect current utilization of science doctorates, but are not responsive to national needs for improvement. They are also based on the present somewhat atypical Federal funding situation. Consequently, modified utilization projections were developed to illustrate the number of Ph.D.'s utilized if recovery to funding growth rates were to occur or if quality and activity changes were to take place. (See appendix D.)

On this basis, R&D funding was assumed to grow at a compound rate of 10 percent per year for Federal R&D obligations and 9 percent per year for industrial support of research and development.

The ratios of doctorate faculty/total faculty were increased as follows: graduate faculty–85 to 95 percent, other 4-year faculty–50 to 75 percent, 2-year faculty–8 to 16 percent.

Although a growth of 0.14 to 0.20 in the ratio of doctorates engaged in "other activities" (management, consulting, technical marketing, industrial operations, secondary school activities, etc.) to total doctorates was utilized in the "basic" utilization projections, these only reflect recently experienced trends which were probably limited by doctorate shortages. Should such shortages become less pronounced it is very likely that relatively more doctorates would be engaged in these activities. Consequently, this ratio was increased further to 0.25.

Table 3 shows the range of such modified utilization projections.

Table 3.–MODIFIED UTILIZATION OF DOCTORATE SCIENTISTS IN 1980
(000)

Type of modification	Method I	Method II
1. No modification (basic projections)	277	301
2. Larger R&D projections	342	337
3. Increase in faculty Ph.D. percent	300	334
4. Increase in ratio of doctorates in other activities/total doctorates from .20 to .25	296	310
5. 2 + 3	365	370
6. 2 + 4	365	349
7. 3 + 4	320	343
8. 2 + 3 + 4	389	383

The above suggested modifications in the utilization pattern of doctorate scientists and engineers are of three general types: (a) level of R&D expenditures, (b) characteristics of faculty in universities and colleges, and (c) the nonresearch and development, nonacademic use within the economy of those trained to advanced levels of education. Obviously, the actual patterns of utilization which will exist in 1980 will not fit the specific situations described. Rather, a variation of these will exist. One effect of such possible changes in patterns is the shift in the concentration of doctorate utilization in universities and colleges. In 1968, nearly 60 percent of the doctorates were engaged in various activities in higher education. Under the several modifications shown, this proportion would range from about 51 percent to 63 percent.

APPENDIXES

7/8

APPENDIX A
1968 Utilization of Ph.D. Personnel in Science and Engineering

Introduction and Summary

It is estimated that, as of January 1968, the stock of Ph.D. level scientists and engineers[1] employed in various activities in the United States was approximately 147,000. The 1968 stock of doctorates was calculated from the numbers of earned doctorates awarded in the years 1920 through 1967 from U.S. institutions, less attrition because of death, and retirement, less allowances for those persons (almost entirely women) not undertaking a career in science or engineering, and less allowances for those foreign citizens who earned Ph.D.'s in the United States, but subsequently left the country. Additions to this stock were made from estimates of doctorates who earned their degrees in foreign institutions, now working in the United States. These calculations of the existing stock in January 1968 are shown in table A-1.

[1] Includes physical, life, and social scientists (excluding historians), mathematicians and engineers. The terms "doctorate," "doctoral" and Ph.D. used in this paper refer to third level research degrees; excluded are professional medical degree personnel.

Table A-1.–ESTIMATED SUPPLY OF PH.D. SCIENTISTS AND ENGINEERS, JANUARY 1968
(000)

Doctorates	Total	Men	Women
Doctorates awarded (U.S.) 1920-67	175.8	161.8	14.0
Immigration of Ph.D.'s, 1920-67	11.0	10.5	.5
Subtotal	186.8	172.3	14.5
Less attrition 1920-67	−24.5	−20.3	−4.2
Less emigration of 1920-67 Ph.D.'s	−15.3	−14.0	−1.3
Subtotal of subtractions	−39.8	−34.3	−5.5
Supply of doctorates, January 1968	147.0	138.0	9.0

A number of sources were used to construct the estimate of the existing stock of doctorates in 1968. These include: information on degrees awarded (from both the Office of Education and the National Academy of Sciences-National Research Council), tabulations and published reports from NSF's National Register of Scientific and Technical Personnel, data from NSF's survey of scientific activities in universities and colleges and a 1965 Bureau of Labor Statistics survey of scientific and technical personnel in industry; and information from several special NSF analyses based on the above and other sources.

Sectoral Employment of Doctoral Scientists

Table A-2 is constructed to show the deployment pattern of the 147,000 Ph.D. scientists and engineers as of January 1968, by employer and by field. Universities and colleges utilize science doctorates in much greater proportions than they do engineers. An estimated 59 percent of all doctorates in science (including social science) and engineering are employed by universities and colleges. Another 26 percent are in private industry or self-employed, and 10 percent work in government agencies–more than 7 percent for the Federal Government alone. The remaining 5 percent are in miscellaneous nonprofit organizations, including Federally Funded Research and Development Centers associated with universities.

In general, about three-quarters of the doctorates in life sciences, mathematics, and social sciences are employed in the universities and colleges; private industry is also an important employer of physical scientists (particularly chemists) and of engineers; more than one-tenth of the life scientists and social scientists are in government positions. The picture is one of employment opportunities in all of the principal economic sectors for doctorates, although much larger numbers are found in institutions of higher education.

Table A-2.–1968[a] UTILIZATION OF PH.D. SCIENTISTS AND ENGINEERS, BY SECTOR AND FIELD

Sector and field	Doctorates	
	Number (000)	Percent
All sectors	**147.0**	**100.0**
Physical scientists	48.7	33.1
Life scientists	37.2	25.3
Mathematicians	8.3	5.7
Engineers	20.1	13.7
Social scientists	32.7	22.2
Universities and colleges	**87.0**	**59.2**
Physical scientists	19.7	13.4
Life scientists	27.7	18.9
Mathematicians	6.8	4.6
Engineers	9.0	6.1
Social scientist	23.8	16.2
Private industry	**38.8**	**26.4**
Physical scientists	23.0	15.6
Life scientists	3.2	2.2
Mathematicians	1.0	.7
Engineers	9.1	6.2
Social scientists	2.5	1.7
Government	**14.1**	**9.6**
Physical scientists	3.5	2.4
Life scientists	5.0	3.4
Mathematicians	.3	.2
Engineers	1.1	.8
Social scientists	4.2	2.8
Nonprofit and other[b]	**7.1**	**4.8**
Physical scientists	2.5	1.7
Life scientists	1.3	.9
Mathematicians	.2	.1
Engineers	.9	.6
Social scientists	2.2	1.5

[a] As of January.

[b] Includes Federally Funded Research and Development Centers attached to universities and colleges.

Source: Derived from data on degrees granted, attrition rates, and immigration and emigration patterns (U.S. Office of Education, Department of Labor, National Academy of Sciences-National Research Council, and National Science Foundation).

Work Activities of Doctoral Scientists

Ph.D. scientists and engineers are currently engaged in a wide variety of activities, including basic and applied research, development, teaching, administration and management, consulting, and a number of other activities. While an individual Ph.D. may engage in more than one activity, e.g., academic scientists engaging in both teaching and research, the deployment of individuals can be described in terms of their "primary" work and principal employer, if more than one. This is the basis adopted for the Method I projections, described in appendixes C and D. On this basis, as shown in table A-3, R&D scientists and engineers account for about 49 percent of the total, teaching for 38 percent and all other activities, i.e., management and administration, production, consulting, technical writing, etc., for the remaining 14 percent. The distribution of doctorate scientists by work activity varies considerably by sector, as shown in the table. Teaching, of course, is paramount in universities and colleges; while research and development is by far the primary activity of most scientists and engineers in the other three sectors.

The extent to which doctorates are "primarily engaged" in research and development varies widely among fields, as shown in table A-4. For example, far more than a majority for physical scientists and engineers are so engaged, but much less of the life and social scientists and mathematicians are in research and development. On the other hand, teaching is the primary activity of about half of the social scientists, mathematicians, and life scientists, but only a minority of the physical scientists and engineers are engaged primarily in teaching.

An alternate approach to 1980 projections was adopted for Method II in appendixes C and D that distinguishes primarily between academic and nonacademic utilization. Doctorates in institutions of higher education were grouped by level of education involved, (graduate, undergraduate, and two-year), rather than separating them into research and teaching activities, as in Method I.

Table A-3–1968[a] UTILIZATION OF PH.D. SCIENTISTS AND ENGINEERS, BY SECTOR AND WORK ACTIVITY

Sector	Total		Percent distribution			
	Number (000)	Percent	Total	R&D	Teaching	Other
All sectors	147.0	100.0	100.0	48.5	37.8	13.6
Universities and colleges	87.0	59.2	100.0	29.6	62.5	7.9
Private industry	38.8	26.4	100.0	78.4	1.0	20.6
Government	14.1	9.6	100.0	63.8	4.3	31.9
Nonprofit and other[b]	7.1	4.8	100.0	90.1	1.4	8.5

[a] As of January.

[b] Includes Federally Funded Research and Development Centers attached to universities and colleges.

Table A-4.–1968[a] UTILIZATION OF PH.D. SCIENTISTS AND ENGINEERS, BY FIELD AND WORK ACTIVITY

Field	Total		Percent distribution			
	Number (000)	Percent	Total	R&D	Teaching	Other
All fields	147.0	100.0	100.0	48.6	37.8	13.6
Physical scientists	48.7	33.1	100.0	63.5	26.1	10.5
Life scientists	37.2	25.3	100.0	39.3	44.6	16.1
Mathematicians	8.3	5.7	100.0	39.8	49.4	10.8
Engineers	20.1	13.7	100.0	65.2	16.4	18.4
Social scientists	32.7	22.2	100.0	29.4	57.5	13.1

[a] As of January.

371-105 O - 69 - 3

11/12

APPENDIX B
Projected Availability of Science and Engineering Doctorates

Introduction and Summary

The future supply of doctorates depends principally upon the current (1968) supply supplemented by new doctorate awards, immigration, and transfers from related fields. Offsetting losses include deaths and retirements, emigration, and transfers to other fields. The following sections review these elements looking to the probable supply in 1980. Summarized in table B-1 is the result of the supply projection exercise, which reaches a level of 352,000 doctorates as of 1980. This level represents an increase of 139.6 percent over the pool of 147,000 doctorates existing in 1968.

Trends in Ph.D.'s Awarded

The growing numbers of baccalaureates, the social pressures to secure higher levels of education, and the greater economic resources available to support graduate study are responsible for the growing number of doctorates awarded each year. The Office of Education reports 5,900 doctorates granted in the "natural sciences and related professions" and social sciences in 1958 and over 14,000, or more than twice as many, in 1968.

Table B-1.–SUMMARY OF AVAILABILITY OF SCIENCE AND ENGINEERING DOCTORATES, 1968 to 1980
(000)

Doctorates	Number
Supply of doctorates, Jan. 1968	147.0
Estimated doctorate awards, Jan. 1968 to Jan. 1980	264.3
Immigration of Ph.D.'s, 1968-80	5.0
Subtotals of additions	416.3
Less attrition from 1968 base	–27.2
Less attrition from 1968-80 Ph.D.'s	–10.6
Less emigration of 1968-80 Ph.D.'s	–26.4
Subtotal of subtractions	–64.2
Supply of doctorates, Jan. 1980	352.1

A projection of doctorates to be awarded between 1968 and 1980 was prepared using the average relationship found in 1960-67 between these degrees and full-time-equivalent enrollment for advanced degrees in science and engineering (counting three part-time students as one full-time-equivalent student), which in turn was based on the OE projection of total graduate enrollments in all fields.[1] This projection, as well as actual data for academic years 1960-61 through 1967-68, is shown in table B-2. The methods used to project these relationships were as follows: enrollment for advanced degrees in science and engineering (EAD) was projected to be a constant 33.6 percent of the projection of graduate enrollment in all fields from 1968 to 1980 (the average for 1960-67); the full-time-equivalent enrollment for advanced degrees, which had increased from 67.5 to 73.5 percent of EAD between fall 1960 and fall 1967, was projected to increase to 78.9 percent by fall 1979 (the same rate of growth adopted for Method II projection in appendix C);[2] and doctorates awarded in science and engineering were projected at a constant rate of 8.3 percent of full-time-equivalent enrollment for advanced degrees in science and engineering (the average for the period 1960-67). This ratio consists of doctorates awarded each academic year related to enrollments in the fall of the same academic year.

Finally, since the period chosen for the analysis of the supply and utilization of science and engineering

[1] See U.S. Department of Health, Education, and Welfare, Office of Education, *Projections of Educational Statistics to 1977-78* (OE-10030-68). Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office), table 12, p. 20. Estimates for 1978-79 and 1979-80 were made by NSF.

[2] This is half the growth that would be obtained by extrapolating the growth of 1960 to 1967. It was chosen arbitrarily, because of the smaller growth in the ratio in the last several years of this period.

Table B-2.–GRADUATE ENROLLMENT AND ENROLLMENT FOR ADVANCED DEGREES AND DOCTORATES AWARDED IN SCIENCE AND ENGINEERING, 1960-61 to 1979-80
(000)

Academic year	Graduate enrollment[a] in all fields	Enrollment for advanced degrees in science & engineering[b]		Doctorates awarded in science and engineering[c]
		Total	FTE	
1960-61	356	120.6	81.4	6.5
61-62	386	128.8	87.1	7.2
62-63	422	142.4	97.3	8.1
63-64	464	158.1	107.3	9.0
64-65	517	177.5	121.6	10.3
65-66	582	195.3	137.9	11.3
66-67	624	207.0	152.0	12.8
67-68	688	224.5	165.0	14.1
1968-69	749	251.7	186.1	16.2
69-70	781	262.4	195.2	16.7
70-71	828	278.2	208.2	17.3
71-72	886	297.7	224.2	18.7
72-73	952	319.9	242.3	20.2
73-74	1,019	342.4	260.9	21.7
74-75	1,085	364.5	279.5	23.3
75-76	1,152	387.1	298.5	24.9
76-77	1,217	408.9	317.1	26.4
77-78	1,279	429.7	335.2	27.9
78-79	1,338	449.6	352.7	29.4
79-80	1,397	469.4	370.4	30.9

[a] Degree-credit resident enrollment in all fields; 1960-61 to 1977-78 from Office of Education and 1978-79 and 1979-80 estimated by NSF.

[b] Total enrollment for advanced degrees; 1960,61 to 1967-68 from Office of Education; 1968-69 to 1979-80 estimated by NSF. FTE enrollment estimated by NSF assuming three part-time students equal one full-time-equivalent students.

[c] 1960-61 to 1968-69 from Office of Education; 1969-70 to 1979-80 estimated by NSF.

doctorates extends from January 1968 to January 1980, allowances were made for degrees granted prior to and after January 1 in academic years 1967-68 and 1979-80, respectively. Data available from the National Academy of Sciences-National Research Council indicate that the proportion of doctorates awarded between July 1 and December 31 has been rising steadily reaching nearly 35 percent in 1967-68. It was assumed that this proportion would reach 40 percent by 1979-80. Thus, 65 percent of the degrees awarded in 1967-68 were not counted in the January 1968 base of 147,000 doctorates, and 60 percent of the projected degrees to be awarded in the latter years were not counted in the supply of doctorates as of January 1980.

Immigration and Emigration Balances

The existing stock of doctorates at any given point in time includes persons who earned their degrees from foreign universities. Over the past several decades, a considerable number of trained scientists and engineers have entered this country as immigrants, and many of these have possessed doctorates at time of immigration. In addition, a number of U.S. citizens have received doctorate training in foreign institutions. Though no exact count exists of these sources, it is estimated that, as of 1968, the number of these doctorates was about 11,000. (The National Register in 1968 provides a minimum count of 6,500, not including engineers, in the population responding to the Register.) Between 1968 and 1980, it is estimated that some 5,000 doctorates will be added to the total national stock from institutions outside the United States.

On the other hand, not all persons earning doctorates at U.S. institutions remain in the United States. In recent years, the proportion of persons receiving the Ph.D. who were not U.S. citizens has been about 15 percent for all fields, according to the survey of earned doctor-

ates conducted annually by the National Academy of Sciences-National Research Council.[3] In some science and engineering fields the ratio has been considerably higher, e.g., engineering (25 percent) and agriculture and forestry (34 percent) and in some fields lower, e.g., psychology (5 percent) and botany and zoology (12 percent). Some of these non-U.S. citizens elect to leave the United States and others remain to pursue their careers in the United States. Information from the NAS-NRC Doctorate Survey indicates that about one-third of the noncitizens expect to be employed outside the United States and a small percentage of U.S. citizens plan likewise. In all between 5 and 10 percent of new science and engineering doctorates plan employment in a foreign country upon receipt of the degree. Some of the noncitizens who remain in the United States initially may eventually return abroad for employment and the U.S. citizens return to the United States. It has been estimated for this report that approximately 10 percent of the total doctorates awarded each year should not be considered as additions to the stock of doctorates in the United States. This proportion has been assumed for all years.

Attrition Due to Death and Retirement

For each year the doctorate population is depleted because of losses resulting from death and retirement. Generalized "tables of working life" for males, prepared by the Department of Labor, have been applied to the cohort of doctorates graduating each year, and losses due to death and retirement have been calculated.[4] For these purposes a median age of 30 years at time of doctorate award was assumed for the male doctorates and attrition was calculated for 5-year intervals. The pattern of working life for females is, of course, considerably different than males. Therefore, only rough approximations were possible.

The attrition from the male doctorate population resulting is estimated as follows for the period up to 1968:

Period	*Male doctorates awarded*	*Attrition*	*Net as of 1968*	*Percent loss*
Total	161,800	20,300	141,500	12.5
1920-59	89,900	19,600	70,300	21.8
1960-67	71,900	700	71,200	.9

[3]National Academy of Sciences - National Research Council, *Doctorate Recipients From United States Universities, 1958-66* and *Summary Report for 1967 and 1968.*

[4] See U.S. Department of Labor, *Length of Working Life for Males, 1900-60* (Manpower Report No. 8, July 1963) and *Work Life Expectancy and Training Needs of Women* (Manpower Report No. 12, May 1967). (Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office.)

The low loss rate for the doctorates of the 1960-67 period results from the young age of the group. The attrition of female doctorates was calculated on the basis of total awards and the estimated number in the population. Some 14,000 women received doctorates between 1920 and 1967, and it is estimated that about 60 percent (9,000) of these were engaged in scientific work as of 1968. (The National Register count as of 1968 was 8,300 not including engineers.) Attrition rates were also calculated for the 1920-67 cohorts of doctorates for the period between 1968 and 1980 at 27,000.

The number of Ph.D.'s awarded between 1968 to 1980 is projected as shown in table B-1. A large proportion of those receiving their degrees in this later period will be less than 40 years of age by 1980. Attrition losses of males from these cohorts are estimated at 3,300 over the 1968 to 1980 period—a little over 1 percent. Attrition of female Ph.D.'s awarded between 1968 and 1980 was estimated at 25 percent over the period.

Population Resources for Doctorate Production

Demographic data and data on the intellectual capacities of our youth indicate that there is and will continue throughout the 1970's to be a substantial reservoir of people potentially available for scientific and other intellectual careers. It is apparent that even with the relatively small number of people obtaining bachelor's degrees in the sciences that both the potential numbers and capabilities are present for producing a continuing high level of doctorates through the 1970's. Projections used in the report show approximately 10 baccalaureates in science and engineering for each doctorate in 1979-80, allowing for a time lag of approximately 5 years from baccalaureate to Ph.D. In the physical sciences and mathematics the ratio is 8:1; in the life sciences, 8:1; in engineering, 7:1; and in the social sciences, 18:1.

Charts A, B, C, and D show the estimated number of baccalaureates with scores of 120 or 130 or over on the Army General Classification Test (AGCT) to reflect the potential for doctorate degrees.[5] It has been estimated that almost 9 out of 10 doctorates in the sciences exceed the 120 score and almost two-thirds exceed the 130 score.[6]

[5]Distributed according to data in *America's Resources of Specialized Talent*, The Report of the Commission on Human Resources and Advanced Training, Dael Woefle, Director. (New York: Harper & Brothers, 1954.)

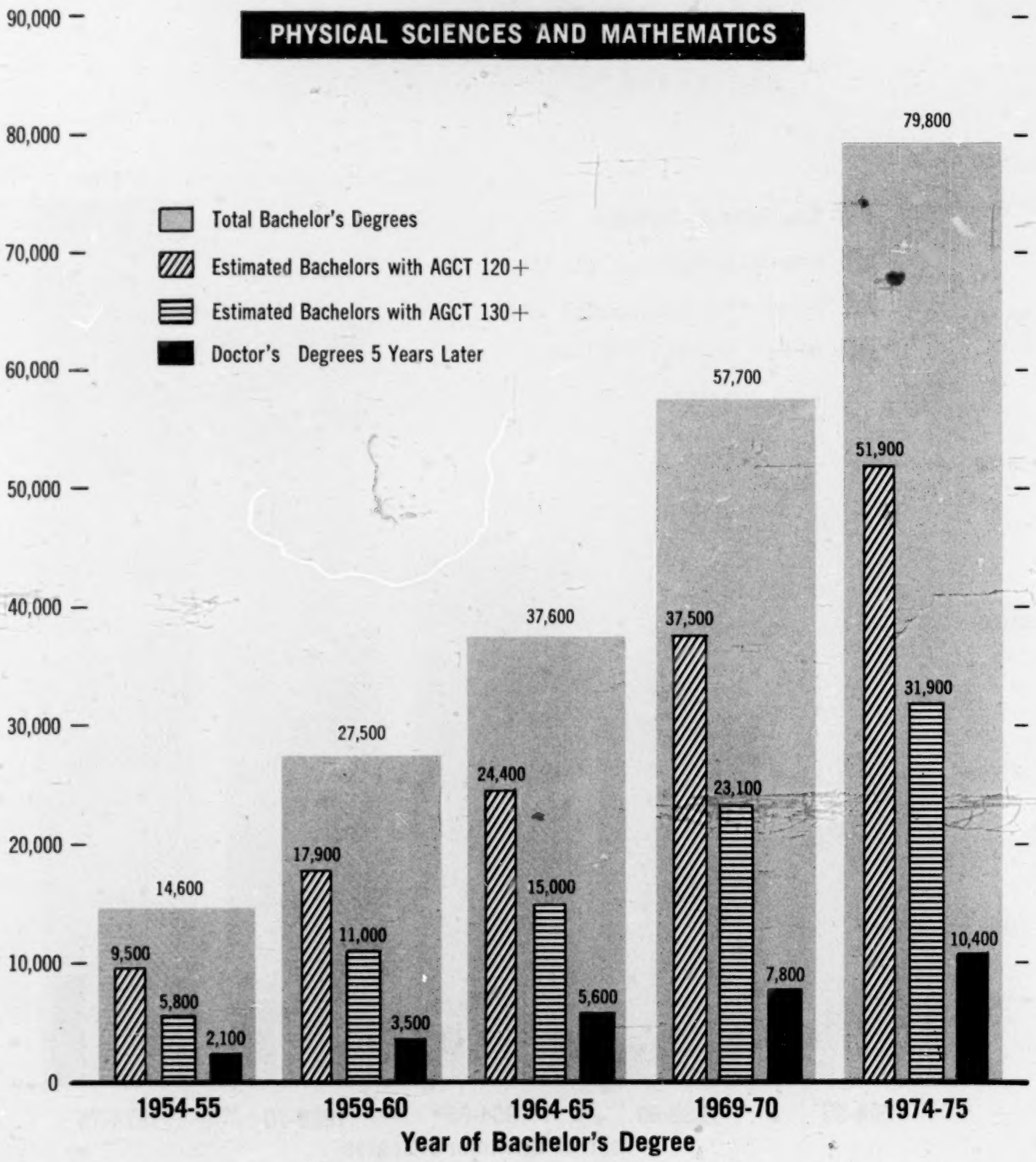
[6]Ibid.

It may be noted from the charts that in the mathematical and physical science fields the ratio of baccalaureates with scores of 130 and over to doctorates 5 years later has attained a level of about 3:1 and is expected to remain at this level through the 1970's. In the social sciences the comparable ratio runs slightly higher than for the foregoing fields. In the life sciences the situation is somewhat tighter, the current ratio being in the neighborhood of 2:1; but this is projected to decline to 1½:1 by 1980. Engineering shows the greatest amount of leeway; with a current ratio of 5:1 and a projected ratio greater than 2:1. Thus, the supply of high AGCT score baccalaureates appears adequate to provide a reservoir for anticipated doctorate production, without deterioration in quality.

In general, about 10 percent of those who receive a bachelor's degree in science or engineering have AGCT scores of 140 or higher; about 25 percent of those who receive a doctorate in science or engineering have such scores. This means that if the number of baccalaureates exceeds the projected number of doctorates by a factor of 2.5, there should be sufficient representation of this high IQ group among the doctorates (assuming a constant distribution of scores among the graduates). All of the projections in the report (illustrated in charts A–D) are well in excess of this ratio.

Chart A – TOTAL NUMBER RECEIVING BACCALAUREATES, BY VARIOUS INTELLIGENCE LEVELS AND NUMBER RECEIVING DOCTORATES 5 YEARS LATER

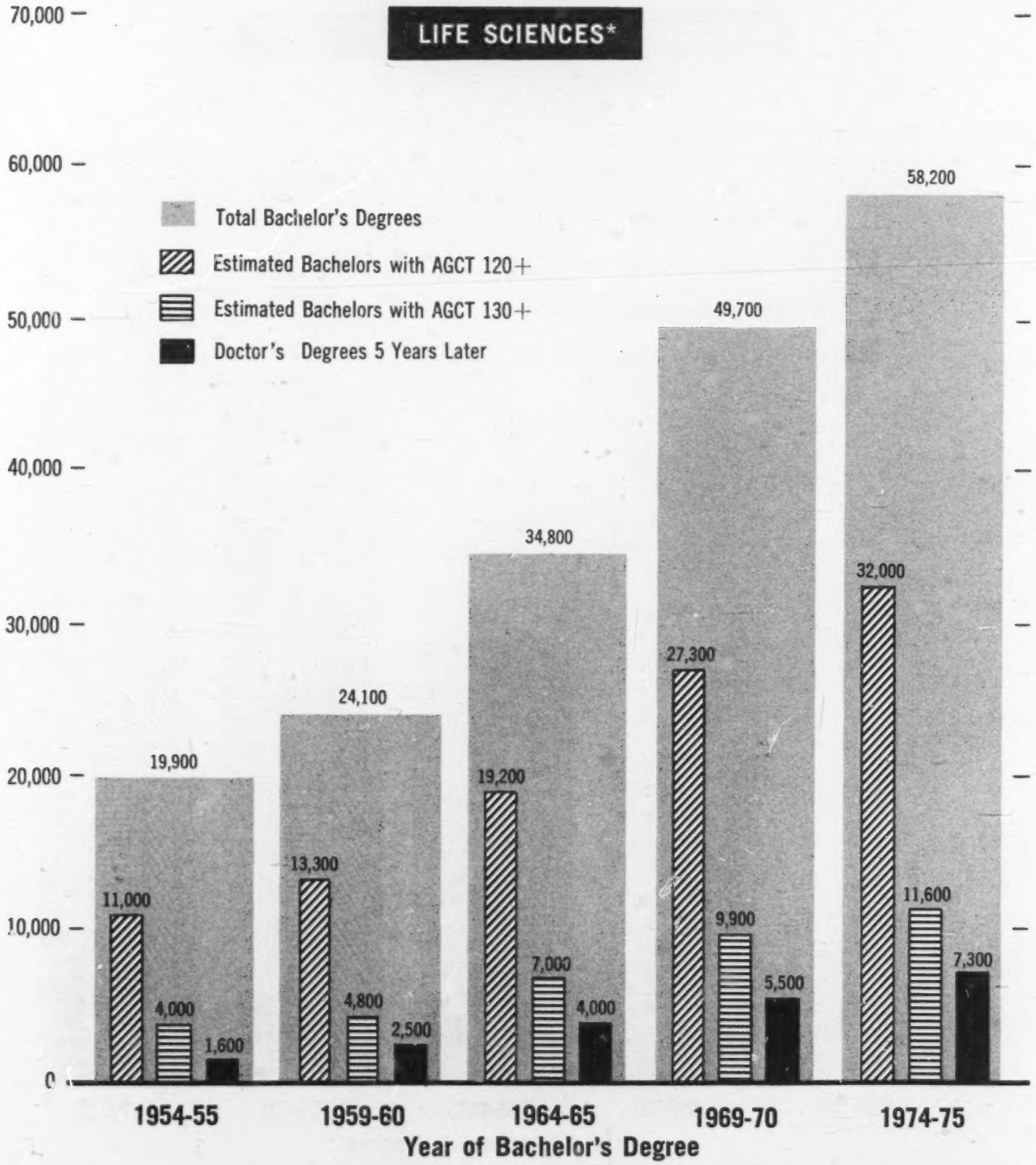
SELECTED YEARS



Sources: U.S. Office of Education, National Science Foundation, and Dael Wolfle, *America's Resources of Specialized Talent.*

Chart B — TOTAL NUMBER RECEIVING BACCALAUREATES, BY VARIOUS INTELLIGENCE LEVELS AND NUMBER RECEIVING DOCTORATES 5 YEARS LATER

SELECTED YEARS

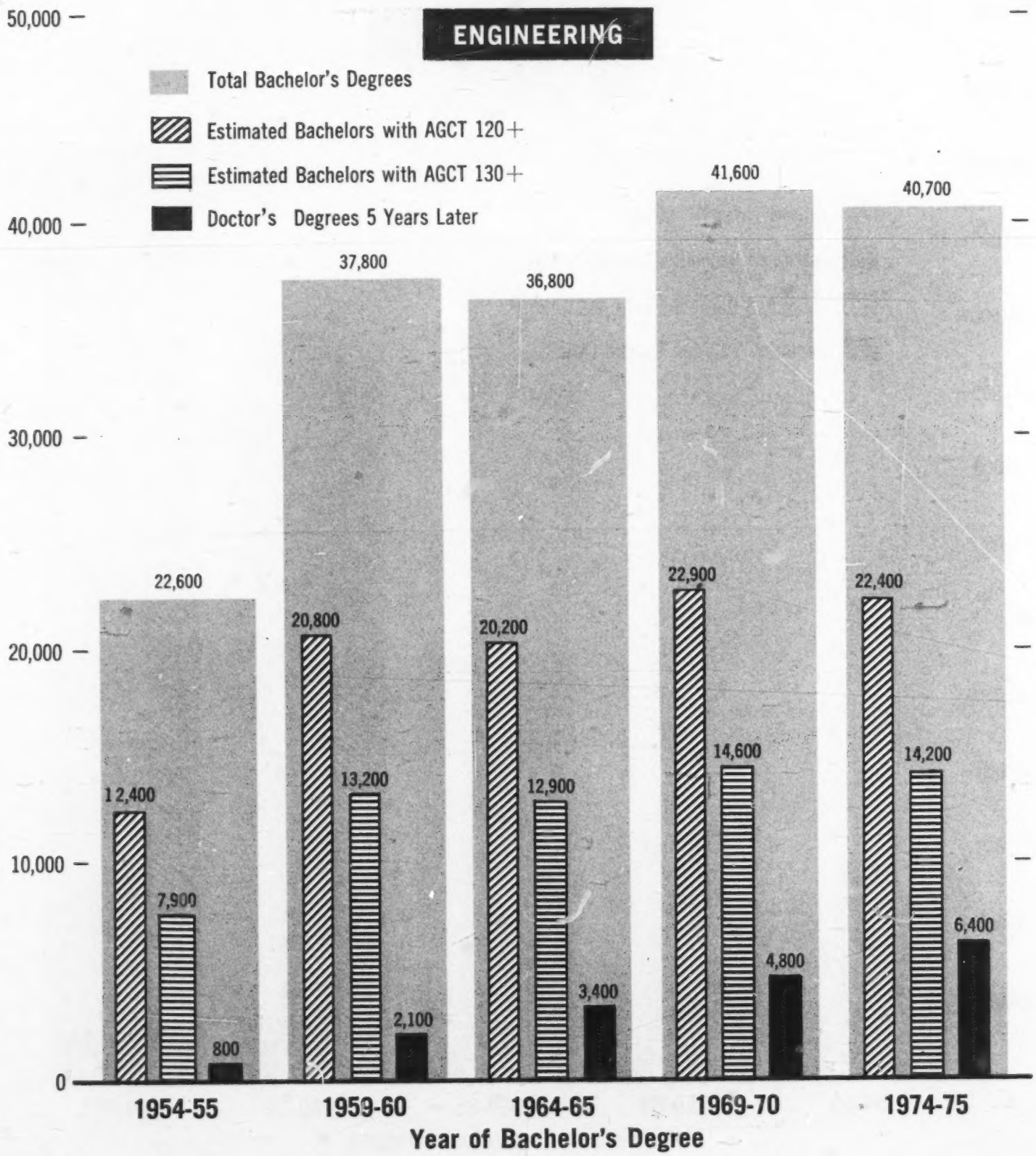


Sources: U.S. Office of Education, National Science Foundation, and Dael Wolfle, *America's Resources of Specialized Talent.*

*Biological and agricultural sciences, and science, general program.

Chart C — TOTAL NUMBER RECEIVING BACCALAUREATES, BY VARIOUS INTELLIGENCE LEVELS AND NUMBER RECEIVING DOCTORATES 5 YEARS LATER

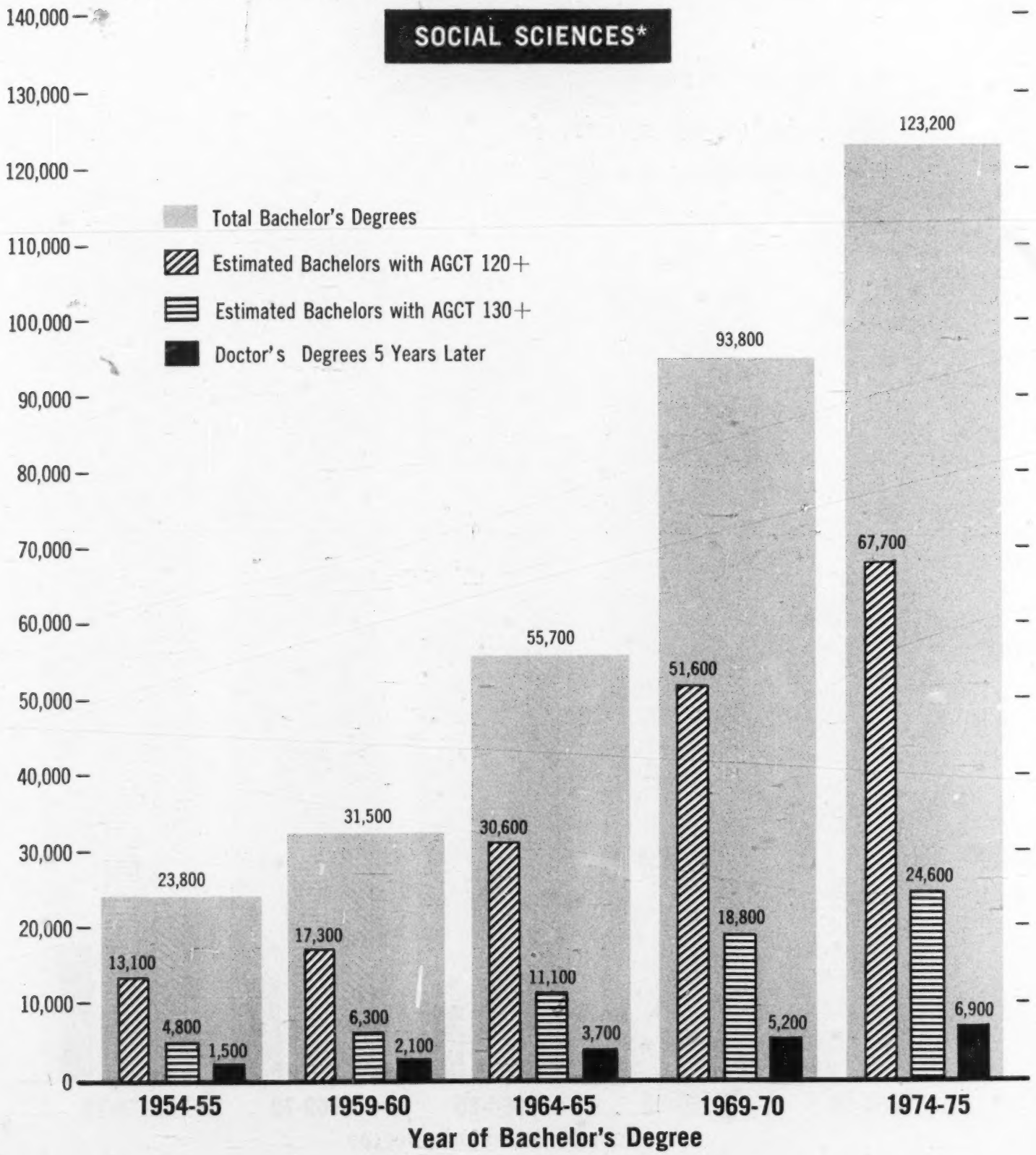
SELECTED YEARS



Sources: U.S. Office of Education, National Science Foundation, and Dael Wolfle, *America's Resources of Specialized Talent.*

Chart D — TOTAL NUMBER RECEIVING BACCALAUREATES, BY VARIOUS INTELLIGENCE LEVELS AND NUMBER RECEIVING DOCTORATES 5 YEARS LATER

SELECTED YEARS



Sources: U.S. Office of Education, National Science Foundation, and Dael Wolfle, *America's Resources of Specialized Talent.*

*Psychology, sociology, anthropology, economics, political science, agricultural economics, geography, and linguistics.

APPENDIX C
Projected 1980 Utilization of Ph.D. Scientists and Engineers

Introduction and Summary

Several methods of projecting 1980 doctorate utilization were investigated. Two are described below. They differ essentially in that Method I relates R&D activity levels of all sectors to possible future R&D funding levels and related teaching doctorates to total expected future academic enrollment levels. Method II relates all academic doctorates, regardless of type of activity, to future enrollments, but projects academic faculty in more detail by level of academic activity (2-year college, 4-year college, graduate and postdoctoral). This then leaves only the nonacademic R&D doctorates to be related to future R&D levels. The first method implies that funding for education will relate only to teaching requirements and the balance of funding to research and development and "other" utilization; the second method assumes that funds for academic activities will be made available on the basis of total educational needs. The methods, although adopting different approaches, do not, as shown below in table C-1, produce drastically different utilization projections. However, it must be pointed out that both projections are conservative in assuming the continuation of existing patterns of doctorate utilization that have been characterized by a Ph.D. shortage. Thus, these numbers represent a minimal situation. Possible improvements of this projected situation are described in appendix D.

Table C-1.–1980–BASIC UTILIZATION PROJECTIONS (000)

Type of activity	Method I	Method II
Total	277	301
R&D	134	
Teaching	88	
Academic	86	
Other	2	
Other	55	
Academic		177
Nonacademic		124
R&D		87
Other and teaching		37

Method I

It has been assumed for the Method I projections that, over the period under consideration 1968-1980, Ph.D. scientists will engage for the most part to the same extent in the same types of activities and for the same types of employers as in 1968 (see appendix A). It is realized that this assumption is not completely valid; there will be changes. For example, new emphasis upon environmental topics may well divert research into these areas, growing enrollments in the junior and community colleges will change the situs of teaching, and doctorates will encounter increasing opportunities in activities other than research and teaching. However, in the absence of a specific basis for determining changes, requirements for doctorates were projected to 1980 generally in terms of the work patterns in which they now engage, i.e., research and development, teaching, and other activities. Table C-2 contains the projected utilization of science Ph.D.'s for research and development, teaching and other activities for 1980, according to the employing sector. The projection of utilization to 277,000 shows an 89-percent increase over the period, or about 5.4 percent per year. This may be compared to the utilization pattern in 1968, shown in table A-3 of appendix A.

Projected R&D Expenditures and Doctorates in 1980

The level of R&D expenditures over the last 15 years has been largely a function of Federal funds available for this purpose. Furthermore, though relative importance may change, Federal funds will continue to be an impor-

Table C-2.–UTILIZATION OF PH.D. SCIENTISTS AND ENGINEERS, BY SECTOR AND WORK ACTIVITY, ESTIMATED FOR 1980[a] (METHOD I)

Sector	Total		Percent distribution			
	Number (000)	Percent	Total	R&D[b]	Teaching	Other
All sectors	277.1	100.0	100.0	48.1	39.9	20.0
Universities and colleges	149.2	53.8	100.0	29.4	57.8	12.8
Private industry	85.2	30.7	100.0	73.3	.8	25.9
Government	28.7	10.4	100.0	52.6	3.8	43.6
Nonprofit and other[c]	14.0	5.1	100.0	86.4	1.4	12.2

[a] As of January.

[b] See tables C-3 and C-4 for basis of utilization in research and development.

[c] Includes FFRDC's associated with universities and colleges.

tant source of support of research and development into 1980. However, in the last few years the pattern of support for R&D activities has been changing. Federal funds in the period 1953-66 (in terms of constant dollars) increased at a compound rate of 11 percent per annum, but amounts budgeted through 1970 show a 1.4 percent annual decrease from 1966 to 1970. In 1968, R&D expenditures totaled $24.9 billion with $14.6 billion, or 59 percent, the Federal share.

One projection provides what may be considered a minimal level for 1980 R&D expenditures. An examination of recent trends in Federal and non-Federal funding of research and development was made to determine the distribution of such support by the end of the 1968 to 1980 period. Federal support for research and development was obtained by using the same compound annual growth rate estimated for the growth in GNP between 1968 and 1980, i.e., 4.4 percent. This rate of growth for Federal funding would reverse the trend of the 1966-70 period, (1.4 percent annual decrease), described in the preceding paragraph, but would fall considerably short of the 1953-66 rate of increase (11 percent). The distribution of Federal R&D support by sector in 1980 was assumed to be proportionately the same as in 1968.

The rate of increase for non-Federal industry and nonprofit organization funds was based on 1962-67 and 1962-66 trend lines respectively, for which data exist. These annual growth rates were 7.6 percent for industry's own funds, 8.4 percent for nonprofit's own funds, and 5.7 percent for other industry support of nonprofit organizations. Academic R&D support was based on maintaining the same growth rate relationship as Federal R&D support to this sector, namely 4.4 percent.

The assumptions above produce a projected level of R&D expenditures of $48.4 billion in 1980 (1968 prices). (See table C-3.) Assuming that Ph.D. scientists and engineers will continue to be employed in the same relationship to R&D dollars in 1980 as in 1968, their utilization by sector can be estimated, as shown in table C-4. The estimated 48.4 billion R&D dollars produces a utilization of over 133,000 doctorates in R&D activities by 1980.

Table C-3.–TOTAL R&D AND FEDERAL R&D EXPENDITURES, 1968 AND PROJECTED TO 1980, BY SECTOR
(Billions of constant 1968 dollars)

Sector	1968		1980	
	Amount	Percent	Amount	Percent
Total R&D performance	$24.9	100.0	$48.4	100.0
Federal Government	3.5	14.1	5.9	12.1
Industry	17.1	68.6	35.1	72.5
Universities and colleges	2.6	10.6	4.4	9.2
FFRDC's (associated with universities)[a]	.7	2.9	1.2	2.5
Other nonprofit institutions	.9	3.8	1.8	3.8
Federal R&D by performer	$14.6	100.0	$24.4	100.0
Federal Government	3.5	24.1	5.9	24.1
Industry	8.3	56.8	13.9	56.8
Universities and colleges	1.5	10.0	2.4	10.0
FFRDC's (associated with universities)[a]	.7	4.9	1.2	4.9
Other nonprofit institutions	.6	4.2	1.0	4.2
Federal R&D as percent of total R&D	*58.6*		*50.4*	
Federal R&D as percent of administrative budget[b]	*11.0*		*11.0*	
Total R&D as percent of GNP	*2.9*		*3.4*	

[a] Federally Funded Research and Development Centers.

[b] Excludes trust funds, such as those for social security, medicare, and highways.

Table C-4.–UTILIZATION OF PH.D.'s IN RESEARCH AND DEVELOPMENT, 1968 and 1980

Sector	Ph.D.'s in R&D (000)	
	1968	1980
Total	71.5	133.4
University and colleges	25.7	43.8
Private industry	30.4	62.4
Government	9.0	15.1
Nonprofit and other[a]	6.4	12.1

[a] Includes FFRDC's associated with universities and colleges.

Note: The projection of R&D expenditures for 1980 is given in appendix table C-3. The projection of Ph.D.'s in R&D assumes that the ratio of expenditures to Ph.D.'s remains constant: (1968 ratios are as follows: universities and colleges, $101,200; industry, $562,500; Federal Government, $388,900; and nonprofit and other, $250,000 per Ph.D.).

Projected Utilization of Doctorates in Teaching in 1980

As in 1968, teaching faculty in universities and colleges are expected to constitute the largest single type (activity within sector) of Ph.D. employment in 1980. A projection of the utilization of doctorates in teaching was prepared using projections of enrollment in institutions of higher education made by the Office of Education. Total degree-credit enrollment is expected to increase nearly 60 percent between academic years 1967-68 and 1979-80. Assuming no change in teaching faculty Ph.D./student ratios, there would be a utilization of about 86,000 science doctorates in teaching in higher education institutions. (See table C-5.) This estimate of utilization for academic teaching is probably minimal in that it does not take into account the differential increases in enrollments in upper division and graduate courses for science and engineering majors, where most science instruction will be found. Miscellaneous teaching and related requirements in other sectors will utilize another 2,000 doctorates.

Table C-5.–PROJECTED UTILIZATION OF PH.D.'s IN TEACHING ACTIVITIES IN UNIVERSITIES AND COLLEGES, 1980
(000)

Academic year	Total degree-credit enrollment	Teaching staff	
		Total (FTE)	Ph.D.'s
1966-67	5,885	112.3	50.4
1967-68	6,348	121.1	54.4
1979-80	10,069	192.1	86.3

Utilization of Ph.D.'s in Other Activities in 1980

As noted in table A-3, appendix A, an estimated 14 percent of science Ph.D.'s were engaged in non-R&D and nonteaching activities in 1968. They are administrators in the universities and colleges, directors of scientific laboratories in industry and government, technical sales representatives in industry, program monitors in government, and consultants for the most part. The use of doctorates in such activities is certain to expand by 1980.

Data from the National Register shows that the proportion of science doctorates in several selected fields (chemistry, physics, mathematics, biology, and psychology) combined engaged in activities other than research and development and teaching increased by 5 percentage points between 1960 and 1968 (from 14 to 19 percent).

The Register does not cover engineers and, information about other fields of science is not available for early years. Lacking a more sound basis for projection, the utilization of doctorates in "other" activities has been extrapolated at the rate of growth indicated for the selected fields in the Register. Thus, the proportion in other activities would rise to about 20 percent by 1980. At this level, utilization in other activities would amount to 55,000.

Method II

In Method I a distinction was made between doctorate holders in colleges and universities who are engaged in teaching and those performing research and development. The former was projected on the basis of *total* college and university enrollments, the latter on the basis of total national support of research and development. A different approach can be considered because:

(1) It is difficult to distinguish between the educational and noneducational aspects of research in academic institutions, especially at the graduate level. Thus, the magnitude of faculty activities in both research and teaching is likely to depend strongly on educational requirements, that is, on enrollments.
(2) Higher education is not homogeneous with respect to either type of institution or level of instruction. Projections should be based on the characteristic growth rates of different classes.
(3) Federal support of academic science and engineering, or of graduate education, may well differ in their rate of growth from that of research and development as a whole.

Accordingly, an alternate method of projection can be used, one that distinguishes primarily between academic and nonacademic utilization. Treatment of the academic portion is based on a central assumption:

> Projections of college and university student enrollments imply projections of faculty utilization. Projections, however, can appropriately be made only for more or less homogeneous subclasses within the academic sector.

The 1968 Academic Distribution

The total number of science and engineering doctorates in U.S. colleges and universities on Janaury 1, 1968 is estimated in appendix A, table A-l, to be

(1) 87,000 Ph.D.'s

The initial problem is to estimate the subsidiary classes within this total. Five such classes have been chosen as follows:

Graduate Faculty–Full-Time: Separate faculties have not developed for the graduate and undergraduate divisions in U.S. colleges and universities. Nevertheless an operational definition is available:

> . . . all individuals of academic rank of instructor or above who are significantly involved in the academic graduate program (i.e., teaching one or more graduate courses or seminars and/or directing research of one or more graduate students).

The full-time component of this group is taken to be the first class. This definition has been used for the collection of departmental data by the NSF Graduate Traineeship Program. From these data the graduate student/graduate faculty ratio for full-time students and faculty can be computed for the sciences and engineering. The average value of this ratio has been taken to be an invariant for this exercise:

(2) 3.14

If this ratio is applied to the full-time and the full-time-equivalent (FTE) of part-time graduate students in science and engineering for the fall of 1967:

	Full-time	135,300
	Part-time (FTE)..	29,700
(3)	Total FTE	165,000

The full-time equivalent of part time is computed as one-third of the part-time enrollments. Thus, the total full-time graduate faculty becomes:

(4) 52,600

It is estimated that the percentage of this faculty who hold the doctorate is:

(5) 85 percent

Hence this class is estimated to contain:

(6) 44,700 Ph.D.'s

Graduate Faculty–Other: In addition to the full-time graduate faculty there are (a) part-time graduate faculty who meet the definition above and (b) nonteaching or research faculty who constitute part of the total environment of graduate education. From the departmental data of the NSF Graduate Traineeship Program the sum of these two groups may be compared with the full-time graduate faculty. The ratio has the average value:

(7) 0.268

Applying this ratio to the full-time graduate faculty **(4)** and using the same percentage **(5)** for those holding doctorates, it is estimated that this class contains:

(8) 12,000 Ph.D.'s

It should be noted that the total graduate faculty, represented by the two classes above, constitutes nearly two-thirds of the total academic utilization of doctorates (87,000) and is substantially engaged in *both* research and development and teaching.

Other 4-Year Faculty: Other faculty members in 4-year colleges and universities in science and engineering who do not meet the graduate faculty definitions above can be estimated as a balancing figure obtained by subtracting from the estimated total academic doctorates **(l)** the sum of **(6)**, **(8)**, **(12)**, and **(13)**, the last two as estimated below. The result is:

(9) 20,500 Ph.D.'s

These persons are largely to be found in institutions that award the baccalaureate or master's degree as the highest degree. From sampling and from NSF survey data it is estimated that this group constitutes about 50 percent of the corresponding nongraduate faculty in science and engineering.

2-Year Faculty: From unpublished tabulations of the American Association of Junior Colleges for academic year 1968-69, adjusted on the basis of the ratio of enrollments in the fall of 1967 to those in the fall of 1968, it is estimated that on January 1, 1968 the science and engineering faculties in 2-year community and vocational colleges totaled:

(10) 22,600

and that of these the percentage holding the doctorate was

(11) 8.12 percent

Applying **(11)** to **(10)** it is estimated that this class contains:

(12) 1,800 Ph.D.'s

Postdoctorals: Only an approximate estimate of these doctorate holders, associated with graduate departments in science and engineering, is currently available from preliminary statistical data from a study being conducted under the National Academy of Sciences-National Research Council:

(13) 8,000 Ph.D.'s

These five classes and the parameters used in computing class memberships form the basis for projecting academic doctorate utilization in 1980. The 1968 distribution for both the academic and nonacademic sectors is summarized in table C-6. The distribution for the latter is the same as that adopted for Method I. (See table C-2.)

Table C-6.–BASIC PROJECTION OF UTILIZATION OF 1980 PH.D. SCIENTISTS AND ENGINEERS (METHOD II)
(000)

Ph.D. scientists and engineers	1968	1980 Basic
Total	147.0	300.7
Academic	87.0	176.5
Graduate faculty–full-time	44.7	100.3
Graduate faculty–other	12.0	26.9
Other 4-year faculty	20.5	30.7
2-year faculty	1.8	3.4
Postdoctorals	8.0	15.2
Nonacademic	60.0	124.2
Research and development	45.7	87.0
Teaching	1.3	2.0
Other	13.0	35.2

Projection of 1980 Academic Utilization

The situation that can be anticipated for January 1, 1980, a "basic" projection, is estimated from the 1968 distribution and student enrollment projections of the Office of Education to the fall of 1977, extrapolated to the fall of 1979 by NSF. In general, a conservative projection is obtained by holding certain parameters constant where only one estimated or computed value is available, even though it can be judged on qualitative grounds that changes may occur prior to 1980 that would increase the projected totals.

Graduate Faculty–Full-Time: Following the procedure above it is necessary to estimate the FTE graduate enrollments for the fall of 1979. Total graduate enrollments in all fields are projected to be

(14) 1,397,000

The percentage of graduate enrollments in the sciences and engineering varied during the 8-year period between 1960 and 1967 from 32.6 to 34.3 percent. No clear trend is exhibited; hence the average value is chosen and assumed to persist to the fall of 1979:

(15) 33.6 percent

Applying **(15)** to **(14)** the projection of graduate enrollments in science and engineering becomes:

(16) 469,400

To compute the FTE enrollments it is necessary to estimate the full-time percentage for the fall of 1979. This percentage has demonstrated a clearly rising trend from 1960 to 1967. The corresponding ratio of FTE to total enrollments was projected to fall 1979 by a least squares computation. However, because of the detailed behavior of this ratio during the 1960-67 time period, it cannot be concluded conservatively that this projected value will prevail. Hence the average of this value and that for the fall of 1967 has been adopted:

(17) 0.789

If this figure is applied to **(16)**, and the student-faculty ratio **(2)** and the estimated doctorate percentage **(5)** are assumed to remain constant, the full-time graduate faculty with doctorates in 1980 becomes:

(18) 100,300 Ph.D.'s

Graduate Faculty–Other: If the ratio **(7)** of this group to the full-time graduate faculty with doctorates is applied to **(18)**, that is, retaining the same doctorate percentage **(5)**, the projected number in this class becomes:

(19) 26,900 Ph.D.'s

Other 4-Year Faculty: The ratio of total projected undergraduate enrollments in the fall of 1979 to that in the fall of 1967 is:

(20) 6,864,000/4,584,000=1.50

If this ratio is applied to the 1968 total of doctorates in this class **(9)**, the projected total for 1980 becomes:

(21) 30,700 Ph.D.'s

Since this class of faculty members relates to the total undergraduate involvement in science and engineering, the projection **(21)** assumes that the pattern of this involvement will not change. It is further assumed that the percentage of this class holding the doctorate will remain constant.

2-Year Faculty: The ratio of total projected enrollments in 2-year institutions in the fall of 1979 to that in the fall of 1967 is:

(22) 2,014,000/1,075,000=1.87

If this ratio is applied to the 1968 total of doctorates **(12)** the projected total for 1980 becomes:

(23) 3,400 Ph.D.'s

The same comments apply for those for Other 4-Year Faculty above.

Postdoctorals: There is no clear basis for projecting the total number of postdoctoral students, since the number is closely related to the support of academic research and development. The ratio of projected full-time graduate faculty for 1980 **(18)** to that for 1968 **(6)** is:

(24) 2.24

The corresponding ratio for doctorates engaged in nonacademic research and development (discussion below) is:

(25) 1.90

A conservative projection may, therefore, be obtained by applying the latter ratio to the 1968 total **(13)**:

(26) 15,200 Ph.D.'s

The projected totals for these five classes, obtained above, are summarized as the "1980 Basic" projection in table C-6.

Projection of 1980 Nonacademic Utilization

As in appendix A, the nonacademic utilization is considered to consist of three parts: research and development, teaching, and other (consulting, administration, etc.). The following projections provide an alternate to those in Method I.

Research and Development: This projection is based upon three principal types of nonacademic R&D funding, each subject to distinctive, though not unrelated, motivations and pressures: (a) non-Federal funding in industry, determined principally by economic considerations; (b) non-Federal funding in nonprofit organizations, determined by various considerations; and (c) Federal funding in the nonacademic sector, determined principally by political considerations. In all three cases an attempt has been made to relate expenditures to the GNP. The latter is assumed to grow in constant dollars with an average annual increase of 4.4 percent. In the following tables ratios were computed in *current* dollars through 1968. The GNP in *constant* (1968) dollars is computed for 1980 to be:

(27) $\$1.44 \times 10^{12}$

Doctorates in each subdivision engaged in research and development (industry and nonprofit organizations) were divided into those supported by Federal or non–Federal funding in proportion to the respective R&D expenditure in 1968. Projections to 1980 are based on the percentage increases between 1968 and 1980 in computed R&D expenditures. It has thus been assumed that R&D expenditures (in constant dollars) per doctorate in the nonacademic sector will remain constant.

Industry–Non-Federal Funding: The ratio of industry funded research and development to GNP for the period from 1956 to 1968 inclusive was used as the basis for a least squares projection to 1980. The industry funded doctorates in research and development in 1968 are estimated to be:

(28) 15,700 Ph.D.'s

The corresponding 1980 figure becomes:

(29) 33,100 Ph.D.'s

Nonprofit Organizations–Non-Federal Funding: Similarly, the ratio of nonfederally funded research and development to GNP for the period from 1956 to 1968 inclusive was used as the basis for a least squares computation. The number of doctorates corresponding to this funding in 1968 is estimated to be:

(30) 1,200 Ph.D.'s

The computed 1980 total becomes:

(31) 3,200 Ph.D.'s

Nonacademic–Federal Funding: The ratio of Federal R&D funding in academic organizations to the Federal administrative budget and the ratio of the administrative budget to GNP were computed for the period 1956 to 1968. The former increased until 1965 and then decreased; no trend is available for projection to 1980, and the average of the values (0.103) for the 13 years is assumed to be representative of the situation in the future. The ratio of the Federal administrative budget to GNP remained substantially constant over the 1956-69 period, and again the average (0.155) is used. The number of doctorates in research and development, supported by Federal funding in the nonacademic sector in 1968, is estimated to be:

(32) 28,000 Ph.D.'s

The corresponding 1980 figure is:

(33) 50,700 Ph.D.'s

The total nonacademic R&D utilization in 1980 is thus projected to be the sum of **(29, (31), and (33)** or:

(34) 87,000 Ph.D.'s

Teaching: No modification of Method I is proposed. The 1968 total has been estimated (table C-2) to be:

(35) 1,300 Ph.D.'s

The 1980 projection is:

(36) 2,000 Ph.D.'s

Other Activities: Again no modification of the procedure of Method I or the estimate for 1968 (appendix A) is proposed. It is necessary, however, to compute a figure for 1980 to correspond to the R&D total **(34)**. From Method I this value, considered as a percentage of nonacademic R&D utilization, may be computed:

(37) 40.5 percent

The corresponding total numbers of doctorates engaged in "other" activities in the two years becomes:

(38) 1968: 13,000 Ph.D.'s

(39) 1980: 35,200 Ph.D.'s

In table C-6 the 1968 distribution and the projected 1980 "Basic" distribution are summarized. The projected 1980 basic utilization figure of 301,000 doctorates in science and engineering is, however, and as noted previously, controlled by ratios and parameters prevailing during and prior to 1968.

APPENDIX D
Possible Modifications of Utilization Patterns

Introduction and Summary

The projections discussed in appendix C are conservative in the sense that (a) generally no changes are presupposed in the proportions of Ph.D. involvement in either the academic or nonacademic sectors, and (b) rates of growth are based on either long-time established trends, or when these were lacking, most recent trends, even if these were lower than those previously experienced. There are, however, several changes that represent existing pressures to increase utilization and that are inherently desirable at the present stage of development of American society. Three types of modifications form the subject of this appendix. They concern (a) the level of R&D expenditures in an expanding and technologically complex economy, (b) the characteristics and quality of the faculty in institutions of higher education as the proportion of the population seeking such education increases, and (c) the use made by society generally of the skills, knowledge, and experience of those who have successfully achieved the highest levels of advanced education.

Recovery of R&D Growth Rate

The basic R&D utilization projections in appendix C for both Method I and II were assumed to be conservative in nature. However, it appears entirely appropriate to consider a return during the next decade to a rate of growth, especially for Federal R&D funding, more comparable with that of the past. The growing technological content of modern life and its increasing dependence upon scientific accomplishment, continually expanding international competition in both scientific activity and technology-based commerce, and ever-increasing awareness of R&D needs and opportunities for contributions to the national health, security, and quality of life all point to potentially higher R&D levels.

Improvement in Faculty Ph.D. Utilization

In two recent studies, one conducted by NSF and one by Allan M. Cartter for the American Council on Education,[1] the common conclusion was reached that a shortage currently prevails with respect to the supply of doctorates available to institutions of higher education, and that this shortage would be relieved after the mid-1970's. This shortage is reflected in the Ph.D./faculty or Ph.D. faculty/enrollment ratios characteristic at all levels of the higher educational process in 1968, and inherent to both Method I and II utilization projections. To improve the quality of the educational experience of an estimated 11 million students enrolled in colleges and universities in 1980, it is appropriate to modify the basic projections of Method I and II by a reasonable growth in these percentages. One way in which this growth can be expected to occur is seen in the fact that the two areas relevant to this study that have presently the *lowest* percentages of faculty holding the doctorate, namely, mathematics and engineering, also have the *highest* recent and projected rates of increase in doctorate production.

Broadening the Scope of Ph.D. Utilization

Apart from the traditional areas of teaching and research and development, an increasing number of doctorates is being employed in a variety of activities. These include administration and management, especially in government and industry, technical consulting, cor-

[1] National Science Foundation, *Science and Engineering Staff in Universities and Colleges, 1965-75* (NSF 67-11) (Washington, D.C. 20302: Supt. of Documents, U.S. Government Printing Office), 1967 and A. M. Cartter, *Future Faculty Needs and Resources* background papers of participants, 49th Annual Meeting, American Council on Education (Washington, D.C.), October 1966.

porate planning, technical marketing, design and manufacturing engineering, and others, as well as a growing number of tasks involving especially the social sciences. This trend is due not only to subject matter specialties but also to the discipline and habits of mind developed over a number of years of demanding apprenticeship. The trend can be expected to continue. Although provision for such "other" utilization and its growth was included in the basic projections of Methods I and II, the amount of such growth was based on the growth experienced during the tight supply situation of the 1960's and noted above in connection with the utilization of Ph.D.'s on faculties.

For these reasons certain essential modifications to the basic projections are proposed as leading to more realistic projections for 1980. If these are computed as shown below, the following possible Ph.D. utilization numbers develop.

Table D-1.–1980–MODIFIED UTILIZATION PROJECTION OF PH.D.'s
(000)

Type of modification	Method I	Method II
1. No modification (basic projections)	277	301
2. Larger increase in R&D	342	337
3. Increase in faculty Ph.D. percentage	300	334
4. Increase in ratio of doctorates in other activities/total doctorates from .20 to .25	296	310
5. 2 + 3	365	370
6. 2 + 4	365	349
7. 3 + 4	320	343
8. 2 + 3 + 4	389	383

Method I Modifications

Recovery of Rates of Growth of R&D Expenditures and Doctorates Utilized

An alternative projection of expenditures for R&D activities provides another possible level of utilization of science and engineering doctorates in 1980. The projection adopted for Method I (appendix C), termed a minimal limit of such activities, indicated expenditures of $48.4 billion and over 133,000 doctorates in 1980.

If it is assumed that the present plateau of Federal funding of research and development is temporary and that non-Federal funding will continue to increase at recent growth rates, a considerably higher level of R&D effort would be projected for 1980. These assumptions include the following: that Federal financing would return to the annual increases of the 1953-66 magnitude (a compound rate of 10 percent for the period 1970-80); that private industry's own funds would be extrapolated at about 9 percent, based on recent growth rates; that the increase in R&D conducted in the academic sector is proportionate to the increase in Federal funding between 1970 and 1980; and that the 1966 relationship of 59 percent Federal funding and 41 percent non-Federal would by 1980 be changed to 55 and 45 percent, respectively. This projection would produce a level of total research and development of $63.6 billion (1968 prices) in 1980. Again, assuming a constant relationship of R&D dollars to doctorates, a utilization of over 185,000 doctorates in research and development would be achieved–52,000 more doctorates than for the basic projection in Method I. Table D-2 shows the sectoral distribution of R&D dollars and doctorates for this alternative projection of R&D effort.

Since the number utilized in "other" activities was assumed to be a constant proportion of those in research and development and teaching, this alternative projection of R&D utilization would also result in an increase of 13,000 doctorates in other activities.

Table D-2.–MODIFIED PROJECTED UTILIZATION OF PH.D.'s IN RESEARCH AND DEVELOPMENT IN 1980

Sector	1980 R&D Expenditures		1980 Ph.D.'s in R&D	
	Billions of dollars[a]	Percent	(000)	Percent
Total	$63.6	100.0	185.5	100.0
Universities and colleges	6.8	14.6	67.2	36.2
Private industry	43.4	68.2	77.2	41.6
Government	9.3	10.6	23.9	12.9
Nonprofit and other[b]	4.3	6.6	17.2	9.3

[a] Constant 1968 dollars.

[b] Includes FFRDC's associated with universities and colleges.

Note: The projection of Ph.D.'s in research and development assumes that the ratio of expenditures to Ph.D.'s remains constant: (1968 ratios are as follows: universities and colleges, $101,200; industry, $562,500; Federal Government, $388,900; and nonprofit and other, $250,000 per Ph.D.)

Teaching Doctorates

As indicated in Method I of appendix C, the projection of the utilization of doctorates in teaching was considered as minimal in that the relationships of faculty doctorates to enrollments was not assumed to improve and that differential increases in enrollments (particularly upper division and graduate) were not taken into account.

In the case of the first relationships, a more optimistic or less conservative assumption, is perhaps more realistic an assumption to make for the end of the next decade. There are considerable grounds for the belief that improvement in the proportion of teaching faculty with doctorates was not possible in past years because of the restrictions on supply and competition from nonacademic employment. The growth in academic science and engineering in terms of enrollments, degrees, and support (from all sources) points to a likelihood that improvement in the proportion of teaching faculty with doctorates is desirable and will be possible in the 1970's.

Applying similar assumptions as to possible changes in the percentage of faculty with doctorates, as used in the modification of Method II projections, a change in the overall proportion of science and engineering teachers can be obtained. The overall percentage (that is considering all classes combined—graduate faculty, other 4-year faculty, 2-year faculty, etc.) was assumed to increase from 45 to 54 percent. If this increase is applied to the basic estimates of utilization of doctorates in teaching in universities and colleges given in appendix C (about 86,000) then an additional 18,000 doctorates would be utilized in this manner in 1980.

As in the case of the modified projection of R&D levels in 1980, the estimated number of doctorates involved in activities other than teaching and research and development would also change with the adjustment of utilization in teaching. This increase in teaching activities would therefore involve an increase of 5,000 doctorates in other activities.

Doctorates in Other Activities

In Method I of appendix C (page 23), the utilization of doctorates in activities other than teaching and research and development was projected to increase from about 14 to 20 percent of the total numbers of available Ph.D.'s. This rise was extrapolated on the basis of selected data for the 1960 to 1968 period. However, past trends in the use of doctorates in these activities have been affected by the short supply of available doctorates, and competition from teaching requirements to meet the increase in enrollments and from national R&D efforts. Furthermore, the engagement of doctorates in activities other than teaching and research and development has been the exception rather than the normal career involvement for these personnel. It is likely that doctorates will increasingly move into and create opportunities in "other" activities.

If instead of a rise to 20 percent, as many as 25 percent of the doctorates were to be found in careers not related to teaching or research and development, an additional 19,000 doctorates would be involved on the basis of the basic projections of research and development and teaching developed by Method I (appendix C). If the ratio of 25 percent is assumed on the basis of the modifications in research and development and teaching utilizations as outlined above, the numbers of doctorates in other activities would increase by 36,000 and 25,000, respectively. If the ratio of 25 percent is assumed for both adjustments combined, an additional 42,000 doctorates would be utilized in other activities. A summary of the modifications to the basic utilization in 1980 under Method I is shown in table D-3.

In 1968 nearly 60 percent of all doctorate scientists and engineers were in universities and colleges. This concentration of doctorate employment would obviously change under the various modified utilization patterns indicated above, ranging from a low of 56 percent under types 2 and 6 to a high of 62 percent under types 3 and 7.

Table D-3.–SUMMARY OF MODIFICATIONS TO BASIC 1980 UTILIZATION
(METHOD I)
(000)

Type of modification	Total	R&D	Teaching	Other
1. No modification (basic projections)	277	133	88	55
2. Larger increase in R&D	342	186	88	69
3. Increase in faculty Ph.D. percentage	300	133	107	60
4. Increase in ratio of doctorates in other activities/total doctorates from .20 to .25	296	133	88	74
5. 2 + 3	365	186	107	73
6. 2 + 4	365	186	88	91
7. 3 + 4	320	133	107	80
8. 2 + 3 + 4	389	186	107	97

Note: Detail may not add to totals because of rounding.

Method II Modifications

The three principal modifications, discussed above, that can be deemed improvements to the situation that existed in 1968 also imply increased utilization in 1980 under the Method II approach:

Increased Ph.D.-to-Faculty Ratios

The total "basic" academic utilization, projected in appendix C, was strongly influenced by the estimated percentages of the faculties of the several types considered who possessed doctorates. These percentages are summarized below, together with adjusted percentages that can realistically be anticipated for 1980, providing sufficient doctorates are available to this sector of the market for doctorates:

	Ph.D. percent		*Increase in utilization*
	1968	*1980*	*(000)*
Total			+33.7
Graduate faculty: Full-time	85	95	+11.7
Graduate faculty: Other	85	95	+3.1
Other 4-year Faculty	[a]50	[b]75	+15.4
2-year faculty	8	[c]16	+3.5

[a] Estimated.

[b] Equivalent to 50-percent increase in Ph.D. percent or in number of Ph.D.'s.

[c] Equivalent to 100-percent increase in Ph.D. percent or in number of Ph.D.'s.

This modification to the 1980 projection is independent of other adjustments and is applied directly to the academic utilization in table C-6.

Recovery of R&D Growth Rate

The projection of nonacademic R&D utilization in appendix C (Method II) was based on least squares computations of ratios of R&D expenditures to the GNP for the period 1956 to 1968. This projection is thus influenced by the decline during recent years in Federal support of R&D. It can be assumed, as an alternative, that the Federal limitation is temporary, that evolving national goals will require increased appropriations for research and development, and that growth rates will recover to the levels experienced during the earlier period.

To form estimates of the effect of this recovery in 1980 the same procedure has been used as that in Method I. However, in order to discount the past few years, the time period chosen for the least squares computations is from 1953 (the beginning of reliable time series data) to 1966 inclusive. The results are as follows:

	1980 basic	*1980 adjusted*	*Increase in utilization*
		(000)	
Total	87.0	109.2	22.2
Industry: non-Federal funding	33.1	35.2	2.1
Nonprofit: non-Federal funding	3.2	3.2	–
Federally funded: nonacademic	50.7	70.8	20.1

Again this modification to the 1980 projection is independent of other adjustments and is applied directly to the nonacademic utilization in table C-6.

"Other" Utilization

On the basis of information available for the 1960's it was estimated for Method I that 20 percent of the total utilization of doctorates in 1980 would be in occupations involving other than research and development and teaching. To apply this to the nonacademic sector recourse was made to the ratio of nonacademic "other" to research and development in the Method I basic projections and applying this ratio to the Method II R&D projection. "Other" utilization, within the purview of this analysis, thus becomes a function of research and development. Two types of adjustments will be made: (a) one corresponding to the unadjusted R&D utilization but, assuming an increase in "other" utilization amounting, in total, to an increase from 20 to 25 percent, hence recognizing for this type of utilization continually increasing opportunity, and (b) an adjustment of the same percentage applied to the adjusted R&D level; the adjustment from 20 to 25 percent is made simply by an *increase* of 25 percent in each case. The results are:

"Other" as percent of total utilization	*"Other" corresponding to: 1980 basic R&D*	*1980 adjusted R&D*
	(000)	
20	35.2	49.0
25	44.1	61.3
Increase in utilization	8.9	26.1

Since this modification of the basic projection is concerned with "other" utilization, the "automatic" increase due solely to R&D adjustment will not be sepa-

rately shown, but will be included with the latter in the summary in table D-4.

It is of interest to note that in 1968 approximately 60 percent of the science and engineering doctorates were in academic institutions; the corresponding percentages for the alternatives in table D-4 are:

	Percent
1.	59
2.	57
3.	63
4.	53
5.	61
6.	51
7.	57
8.	55

Table D-4.–SUMMARY OF MODIFICATIONS TO BASIC 1980 UTILIZATION (METHOD II)
(000)

Type of modification	Total	Academic	Non-academic
1. No modification (basic projections	301	177	124
2. Increase in ratio of doctorates in other activities/total doctorates from .20 to .25	310	177	133
3. Increase in faculty Ph.D. percentage	334	210	124
4. Larger increase in nonacademic R&D	337	177	160
5. 2 + 3	343	210	133
6. 2 + 4	349	177	173
7. 3 + 4	370	210	160
8. 2 + 3 + 4	383	210	173

Note: Detail may not add to totals because of rounding.

APPENDIX E
Selected Bibliography and Sources of Data

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